Draining of Superfluid Helium from Porous Materials

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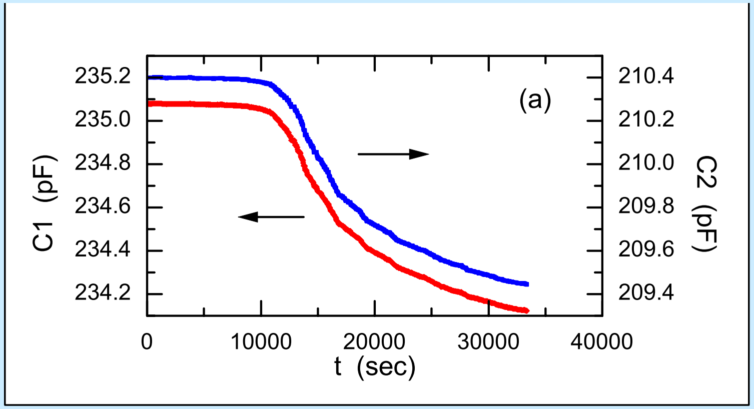
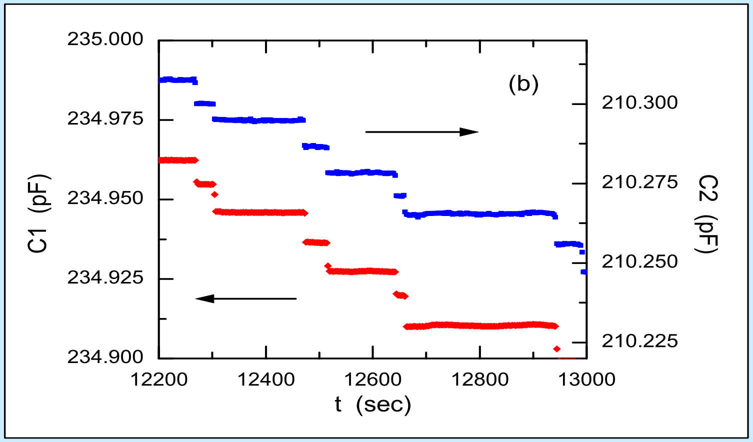
The understanding of the behavior of ordinary fluids in porous materials such as water or oil in sand or porous rock have practical applications with wide economic importance ranging from energy to agriculture and domestic water supplies. Studies of capillary condensation and fluid draining phenomena are thus critically important and have been studied in a model system: superlfuid helium in the porous materials Nucleore and Anopore. Such materials have non-trivial porous structure and the use of helium allows the phenomena to be studied revealing some of the fundamental behavior ordinarily masked by viscosity. Viscosity is absent in superfluid helium, which makes it an ideal fluid to study such phenomena.

Surprisingly, when helium drains from either of these materials, it drains in a series of well-defined avalanches. Shown at the right is an example of data for helium draining from a Nuclepore sample from two detectors as a function of time as helium is withdrawn.

The expanded view at the bottom shows the avalanche behavior. The correlated behavior from two detectors shows that the phenomena is sample-wide.





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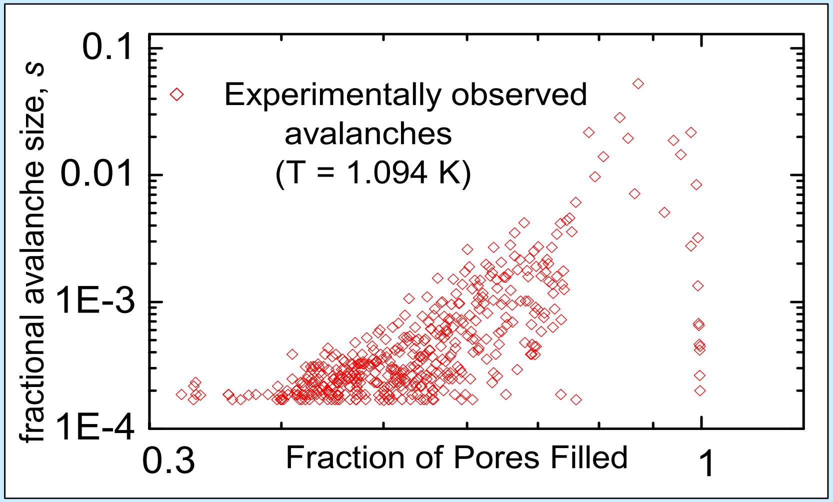
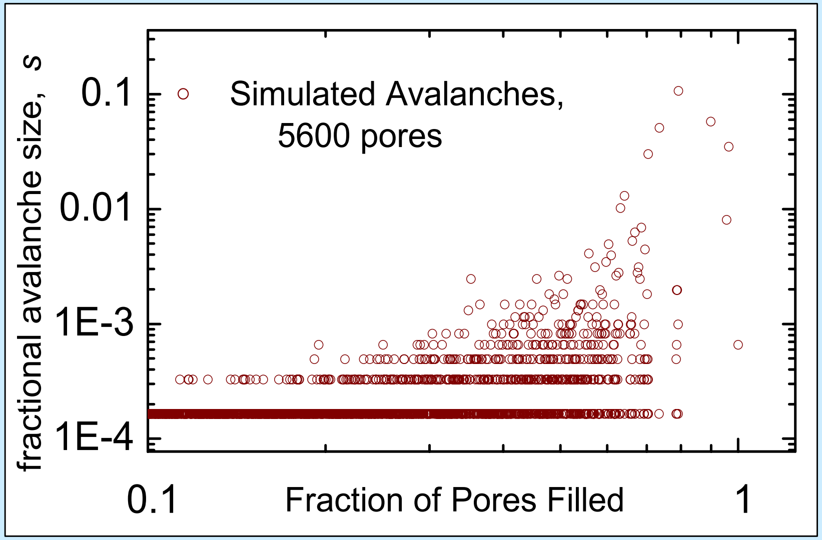
The statistics of the avalanche behavior show interesting behavior that is similar for Anopore and Nuclepore, even though the two materials have different internal pore structures. Shown at the upper right is the avalanche size distribution for Nuclepore. (Data shown is the avalanche size as a function of the extent of sample draining.) Similar behavior is seen for Anopore, which indicates that there is some pervasive fundamental behavior that is common to both of these porous systems. Simulations have been carried out in an attempt to model this behavior and isolate the important characteristics. Pore-pore coupling is critical as its presence in the model allows a simulation (bottom plot) to mimic the experimental observations.

Educational: This work was carried out with Michael Lilly and Adrienne Wootters (graduate students).





Specific Heat and Magnetization of ^{3}He – ^{4} He Mixture Films
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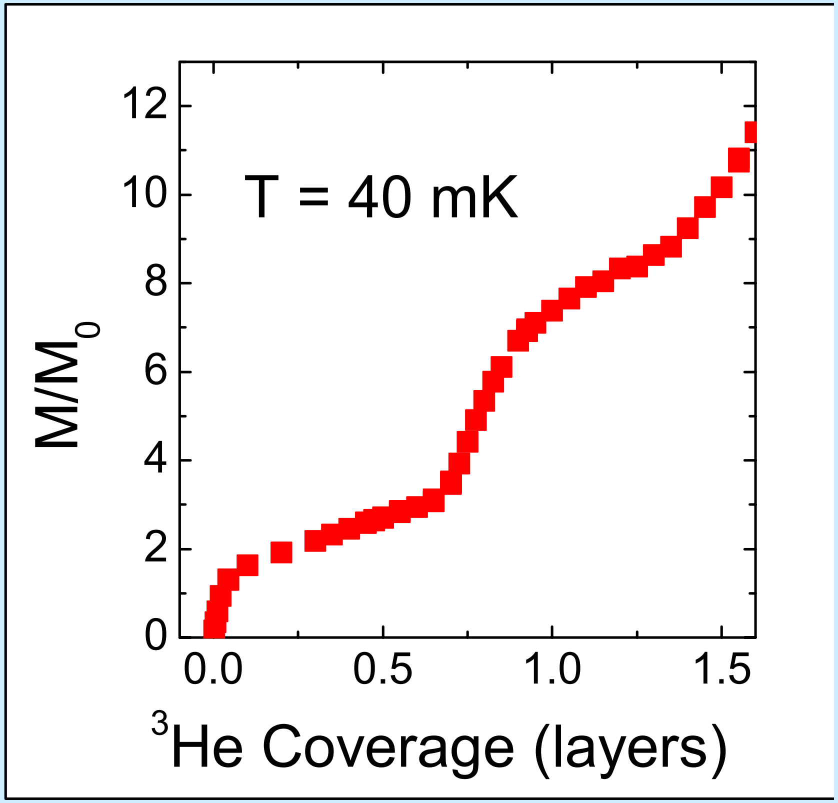
In rough analogy with a cork that floats on a pond, at very low temperatures ^{3}He atoms float atop thin films of ^{4}He. In this situation the ^{3}He atoms live in a nearly ideal two-dimensional world. Study of such ^{3}He atoms, known as Fermi particles, provides unique insight into the behavior of the interactions among such atoms in two dimensions. This in turn informs us about the fundamental behavior of interacting atoms and leads to improved understanding of the behavior of atom-atom interactions generally. Carry-over applications include device development and the study of phase transitions.

Previous measurements supported by NSF-DMR resulted in the discovery of a remarkable step-structure in the magnetization of the two-dimensional ^{3}He atoms. This behavior is shown at the right as a function of the ^{3}He coverage in fractions of an atomic layer.



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Measurements of the heat capacity have now been made (and are continuing). These, when combined with the previous measurements of the magnetization allow a determination of the interactions among the ^{3}He, characterized by what are known as the Landau parameters. These interactions grow stronger with increasing density of the ^{3}He atoms. Superfluidity has been predicted for this two-dimensional system. These Landau parameter results tell us that the interactions are attractive for what is known as the p-state. This will guide the search for the predicted unique new type of superfluidity.

Educational: This work was carried out with Pei Chun Ho (postdoc), with help from Rob Jasperson (high school student).